



Preoperative Variation of Quadriceps and Hamstrings Isokinetic Strength with Time from Injury to Anterior Cruciate Ligament Reconstruction

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Abstract

Objectives: The aim of this study is to assess pre-operative quadriceps and hamstring strength at various time points after ACL injury but prior to ACL reconstruction.

We hypothesized that less side-to-side strength deficit would be noted at longer time points following ACL injury.

Methods: One hundred patients underwent isokinetic muscle strength testing prior to planned ACL reconstruction. Patients were grouped based on time from injury to testing: <3 months (n=55), 3 to 6 months (n=31) and 6 to 12 months (n=14). Among these 3 groups, hamstring and quadriceps Limb Symmetry Index (LSI) and Hamstring/Quadriceps (H/Q) ratios were compared.

Results: There were no significant differences between patients in the three groups in regards to age, BMI, or flexion range of motion, but there was a greater proportion of female patients in the 6 to 12 months group when compared to the other groups. No significant differences in quadriceps or hamstring strength were noted among the three groups. H/Q ratio was significantly increased at 240°/s in the 6-to-12-month group when compared to earlier time points. No correlation was found between patient sex and LSI or H/Q ratios.

Conclusion: Patients who underwent isokinetic muscle strength testing 6 to 12 months following ACL injury demonstrated a higher hamstring/quadriceps ratio at 240°/s than those who were testing within 6 months of injury, but no differences in hamstring or quadriceps LSI were noted based on time.

Time-based criteria to allow for strength recovery prior to ACL surgery seems to be not recommended.

Keywords: Anterior cruciate ligament; Reconstruction; Strength deficit; Muscle recovery

Introduction

Anterior Cruciate Ligament (ACL) rupture is a common injury in athletic populations [1-3]. The management of patients with ACL injuries is increasingly multidisciplinary, with the goal of a quick and safe return to sport [4]. The evaluation of post-operative muscle strength recovery is now an integral part of the rehabilitation process. Numerous studies have shown the importance of recovery of muscle strength for successful return sport [5,6] without high risk of re-rupture [7].

Isokinetic muscle strength testing is frequently performed as an objective measurement of muscle recovery during rehabilitation [8,9]. While strength recovery is an important focus throughout post-operative rehabilitation, muscle strength loss in the affected limb begins as soon as the injury occurs. In order to maximize early strength restoration post-operatively, preoperative muscle recovery must also be considered [10]. Many authors have evaluated the evolution of the postoperative strength deficits and noted an association with preoperative strength [11-13].

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In spite of the known impact of preoperative strength on recovery after surgery, there is limited literature exploring factors that could influence preoperative strength. Of particular interest is the relationship between time from injury and preoperative hamstring and quadriceps strength. The aim of this study is to assess preoperative quadriceps and hamstring strength at various time points after ACL injury but prior to ACL reconstruction. We hypothesized that less side-to-side strength deficit would be noted at longer time points following ACL injury.

Methods

Population

A retrospective study was performed based on prospectively collected data. All procedures were performed following institutional board approval and in accordance with the ethical standards of the 1964 Helsinki declaration and its later amendments. Patients who underwent ACLR between July, 2020, and April, 2022, at one academic center were eligible for inclusion in the study if that had undergone preoperative isokinetic muscle strength testing within one year of their ACL injury. Patients were excluded from the study if they did not undergo preoperative isokinetic muscle strength testing or the time from ACL injury to isokinetic muscle strength testing was greater than one year, to rule out old ruptures of the ACL. During this period, preoperative isokinetic muscle strength testing was generally performed on all patients undergoing ACL reconstruction with the exception of those who could not undergo testing due to pain or the presence of multi-ligament injuries, bucket handle meniscus tears, or other associated lesions. Rehabilitation before surgery was mandatory only in cases of deficit of range of motion.

Data collection and analysis were carried out in accordance with MR004 Reference Methodology from the Commission Nationale de l'Informatique et des Libertés (Ref. 2226075) obtained the April 19th, 2022. The study was registered and filed on the Health Data Hub website.

Patient demographic data were collected including age, sex, Body Mass Index (BMI), Tegner activity scale and knee range of motion at the time of isokinetic muscle strength testing. Patients were divided into three groups based on time from ACL injury to isokinetic muscle strength testing (<3 months, 3 to 6 months, and 6 to 12 months).

Isokinetic muscle strength testing

Isokinetic muscle strength testing was performed using the Contrex (Physiomed Elektromedizin AG, Germany) machine. A standardized protocol was used, beginning with 15-minute warm-up on a stationary bike. For each testing condition, patients performed several submaximal trials for familiarization with the procedure, then maximal effort testing on the uninjured side followed by the injured side. Concentric testing of the hamstring and quadriceps was performed first, with three repetitions at 60°/s, then three repetitions at 240°/s. Eccentric tests of the hamstrings were then performed with three repetitions at 30°/s. Tests were done with a 70° range of motion (20-90°).

Based on the higher of the three repetitions, Limb Symmetry Index (LSI) comparing the injured side to the uninjured side (percentage) was calculated using peak torque (in Newton-meters), for the quadriceps and hamstring muscle groups. For each concentric condition, the Hamstrings/Quadriceps (H/Q) ratio was calculated.

Statistics

Continuous variables were compared among the three time-based groups using Kruskal-Wallis's test and Bonferroni post hoc test was used in case of significant difference. Categorical variables were compared among the three groups using Fisher's exact tests. Isokinetic muscle strength testing results were compared based on sex using Mann-Whitney U tests. All analyses were performed using XLSTAT Software (V2021.1, Addinsoft, Paris, France), with a p-value <0.05 considered statistically significant.

Results

In the study period, 202 patients underwent primary ACL reconstruction in the department. After exclusion of 31 patients with a history of an ACL tear greater than 12 months prior to presentation, 7 patients with multi-ligament knee injuries, and 64 patients who did not undergo preoperative isokinetic muscle strength testing, 100 patients were eligible and included in study (Figure 1).

Patients were grouped based on time from ACL injury to isokinetic muscle strength testing, yielding 55 patients who underwent testing with three months of ACL injury, 31 patients who underwent testing between 3- and 6-months following ACL injury, and 14 patients who underwent isokinetic muscle strength testing between 6- and 12-months following ACL injury.

The overall study population consisted of 69 males (69%) and 31 females (31%) with a mean age of 29.1 years and a mean BMI of 24.3 kg/m². The mean overall time from injury to isokinetic muscle strength testing was 81 days. There were no significant differences between patients in the three groups in regards to age, BMI, Tegner activity scale or flexion range of motion, but there was a greater proportion of female patients in the 6 to 12 months group when compared to the other groups (Table 1). 31 patients did not undergo rehabilitation before surgery. (14 patients in the <3 months group, 13 in the 3 to 6 months group and 4 in the >6 months group).

Isokinetic muscle strength testing

The mean overall quadriceps LSI was 81.2 ± 23.6% at 60°/s and 83.6 ± 22.1% at 240°/s. The mean overall hamstring LSI was 85.3 ± 20.9% at 60°/s, 90.1 ± 19.3% at 240°/s, and 81.9 ± 19.6 with eccentric

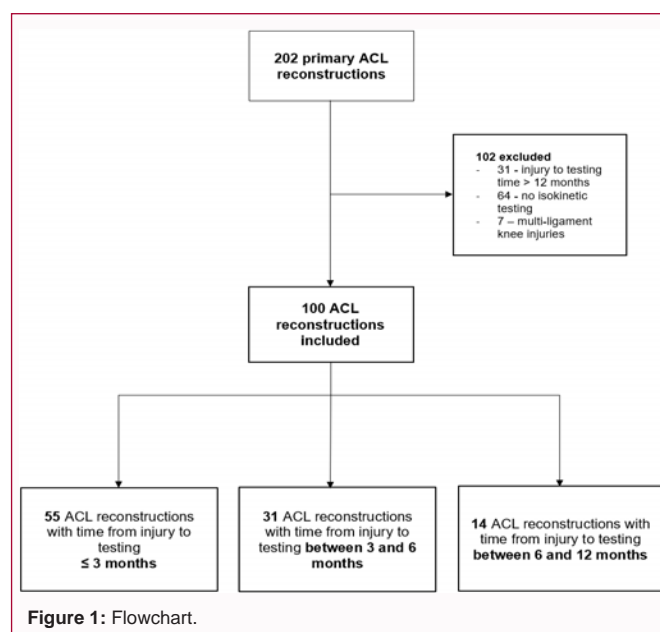


Table 1: Demographics and range of motion.

	Time from injury to surgery			Significance
	<3 months (n=55)	3 to 6 months (n=31)	6 to 12 months (n=14)	
Sex				p=0.02
Female	18 (33%)	6 (19%)	7 (50%)	
Male	37 (67%)	25 (81%)	7 (50%)	
Age in years (Mean ± SD)	27.6 ± 10.4	31.4 ± 11.9	29.6 ± 12.1	p=0.384
BMI in kg/m ² (Mean ± SD)	24.6 ± 4.9	24.7 ± 3.5	24.7 ± 10.4	p=0.674
Days from injury to surgery (Mean ± SD)	56.2 ± 21.3	128.1 ± 28.7	272.1 ± 70.1	p<0.001
Tegner Activity Scale	6.8 ± 1.8	6.5 ± 1.8	6.1 ± 1.3	P=0.361
Range of motion				
Flexion in degrees (Mean ± SD)	131 ± 15	134 ± 11	137 ± 8	p=0.406
Flexion contracture >5 degrees	4 (7.3%)	7 (22.6%)	0 (0%)	p=0.060

Table 2: Isokinetic muscle strength testing LSI (using Peak Torque) by time.

	Time from injury to surgery			Significance
	<3 months (n=55)	3 to 6 months (n=31)	6 to 12 months (n=14)	
Concentric Tests at 240°/s (Mean ± SD)				
Hamstring	89.0 ± 18.2%	90.5 ± 22.2%	91.9 ± 19.6%	p=0.90
Quadriceps	84.5 ± 18.9%	81.8 ± 27.7%	84.6 ± 20.8%	p=0.99
Concentric Tests at 60°/s (Mean ± SD)				
Hamstring	81.6 ± 21.4%	87.8 ± 19.1%	93.7 ± 21.3%	p=0.15
Quadriceps	81.9 ± 18.8%	81.4 ± 29.0%	85.5 ± 21.0%	p=0.92
Eccentric Tests at 30°/s (Mean ± SD)				
Hamstring	77.7 ± 19.8%	86.0 ± 20.6%	89.3 ± 19.3%	p=0.12
Hamstring/Quadriceps Ratio				
Concentric at 240°/s	75.8 ± 16.7%	76.8 ± 42.7%	96.6 ± 48.4%	p=0.020
Concentric at 60°/s	62.7 ± 15.0%	68.6 ± 32.1%	84.3 ± 56.7%	p=0.33

Table 3: Isokinetic muscle strength testing LSI (using Peak Torque) by sex.

	Male (n=69)	Female (n=31)	Significance
Concentric Tests at 240°/s (Mean ± SD)			
Hamstring	88.8 ± 18.3%	93.0 ± 21.2%	p=0.51
Quadriceps	83.8 ± 23.0%	84.0 ± 20.4%	p=0.96
Concentric Tests at 60°/s (Mean ± SD)			
Hamstring	85.9 ± 20.6%	83.9 ± 21.7%	p=0.82
Quadriceps	82.0 ± 23.0%	81.3 ± 21.6%	p=0.66
Eccentric Tests at 30°/s (Mean ± SD)			
Hamstring	82.6 ± 20.0%	80.3 ± 19.8%	p=0.72
Hamstring/Quadriceps Ratio			
Concentric at 240°/s	80.6 ± 37.6%	76.1 ± 16.5%	p=0.947
Concentric at 60°/s	70.0 ± 35.1%	62.8 ± 12.3%	p=0.917

testing at 30°/s. No significant differences in quadriceps or hamstring LSI was identified based on the time from injury to isokinetic muscle strength testing (Table 2). The hamstring/quadriceps ratio was noted to be significantly higher in the 6 to 12 months group when compared to the less than 3 months and 3 to 6 months groups with concentric testing at 240°/s (with respectively a p=0.05 and p=0.006 at Bonferroni test) (Bonferroni corrected significance level: 0.0167). No differences based on time from injury to testing were noted under other testing

conditions (Table 2).

No differences in isokinetic muscle strength testing were found based on patient sex (Table 3).

Discussion

The most important finding of this study is that there was no significant difference in quadriceps or hamstring isokinetic LSI

testing based on time from ACL injury to isokinetic muscle strength testing. However; a significantly higher hamstring/quadriceps ratio was noted in the 6-to-12-month group compared to the other two groups with concentric testing at 240°/s. This finding is in contrast to our hypothesis that less side-to-side strength deficit would be noted at longer time points following ACL injury.

A similar lack of clear correlation between lower extremity strength and time from injury has been noted by other authors. Wojtys et al. [14] studied lower extremity strength in 100 patients with ACL injuries that were treated non-operatively. Patients were grouped based on the time from injury to testing (up to 18 months). These patients were compared with healthy control and it was noted that the patients with the best muscle strength in all groups were similar to controls, while a substantial portion of patients in each group demonstrated ongoing weakness compared to controls – particularly in the quadriceps.

A clear understanding of factors that influence preoperative isokinetic muscle strength testing (including time from injury to surgery) is important given associations noted between preoperative strength and post-operative strength recovery. Riesterer et al. [15] in 2017, studied 80 primary hamstring ACL reconstruction patients with preoperative and 6-month post-operative isokinetic testing. They noted that postoperative strength was strongly correlated with preoperative strength and confirmed the adverse impact of low post-operative strength on knee function.

In the current study, there are signs that recovery of the quadriceps and hamstring muscle groups following ACL injury do not follow the same course. A trend toward recovery hamstring strength with increasing time from injury was noted, although the differences did not reach statistical significance. This trend was also reflected in evolution of H/Q ratios over time, with a significant increase in the H/Q ratio at high speeds with time.

This differential recovery between quadriceps and hamstring strength following ACL injury has been noted by other authors. Tsepis et al. [16], noted this difference after ACL injury in 36 amateur soccer players, with total recovery of hamstring muscle strength but persistent quadriceps weakness at 1 year following injury. In the post-operative setting, Olivier et al. [17] found complete recovery of hamstring strength by 4 months post operative, but persistent quadriceps weakness at that time point.

Given the negative impact of post-operative quadriceps strength on outcomes and the correlation between preoperative and post-operative strength, numerous authors have evaluated the effectiveness of preoperative rehabilitation programs. More intensive preoperative rehabilitation resulted in better functional results in the short [18] and longer term [19,20] postoperatively (up to 2 years). These correlations have also led to a focus on the goal restoring quadriceps during post-operative rehabilitation [21-23].

There are several limitations of the current study. The largest limitation is the cross-sectional study design. Because isokinetic muscle strength testing was only performed at one time point on each subject, it is not possible to study the evaluation of deficits over time in individual patients. Second, the higher proportion of female patients could interfere. Then, although the numbers in the study are large compared to prior work, the study likely remains underpowered to detect strength differences between groups due to the high variability in isokinetic muscle strength values. Further, the

preoperative rehabilitation protocol was not standardized, leading to a heterogeneous population. Finally, there may be other differences between the patients tested at different time points that are not known or controlled for. These differences may confound the results.

Conclusion

Patients who underwent isokinetic muscle strength testing 6 to 12 months following ACL injury demonstrated a higher hamstring/quadriceps ratio at 240°/s that those who were testing within 6 months of injury, but no differences in hamstring or quadriceps LSI were noted based on time.

Time-based criteria to allow for strength recovery prior to ACL surgery seems to be not recommended.

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